Once the team had delineated the potential restoration footprints for each feature, designers began developing scaleable designs and cost estimates. In addition, for any features introducing additional resources, the designers provided relative levels of freshwater introduction and land building for each level. The team developing the features was then able to make preliminary estimates of the ecological output (in acres created) that each feature would produce. In addition to any available land-building estimates, the teams considered current land-loss rates within each footprint and estimated the degree that this rate might be reduced by the considered feature. This allowed the team to estimate acres protected by each feature as well. The team also made initial assessments of the positive, negative, or neutral fit of the features to the major goals and objectives established for the study. This positive, negative, or neutral assessment was also made for each feature against a broad range of significant resources. These assessments were used to identify and screen any features that would not support the environmental goals of the study.

5.0 DEVELOP AND EVALUATE ALTERNATIVES – SELECT A FINAL ARRAY OF COASTWIDE FRAMEWORKS (PHASE IV)

Due to the number of possible restoration features and scales, as well as the number of possible combinations, the effort of developing all possible framework outputs was unmanageable within even a standard study timeframe. The assembly of alternative frameworks using study criteria, best available information, and professional judgment was adopted as an acceptable method to establish model scenarios. The evaluation of these frameworks developed across the range of identified output scales that would then provide an evaluation framework from which relative effectiveness and completeness of frameworks could be gauged.

Utilizing the ecological criteria established in the initial phase of the study, these teams combined the restoration features into alternative frameworks capable of achieving the various identified restoration scales. The alternative development teams utilized the broader goals, principles, and guidelines to formulate criteria for creating similar alternative groups of features across the ranges of restoration scales in each subprovince. Applying the ecological criteria and the output projection established for each restoration feature, each alternative development team developed several significantly different frameworks for each desired subprovince output level. An initial framework for formulation goal was an array of ten alternative frameworks (including No Action) for each subprovince.

The PDT selectively used existing hydrodynamic and ecological models, as well as agency and academic expertise, on a limited number of alternative frameworks in each subprovince to produce a base of information. "Desktop" hydrologic and ecological models were developed based on the numeric modeling output. The application of these desktop models to the remaining alternative frameworks was undertaken by the PDT members. From the desktop model output for each alternative, based on the combined effects of the individual features, the PDT produced benefit assessments for the framework alternatives. These assessments were also completed for any discreet, combinable features. The ecological effects of the alternative frameworks were documented using multiple ecological output metrics.

With a "toolbox" of restoration features developed and a range of quantitative scales for the study identified, the next plan formulation step was to assemble a variety of alternative frameworks for meeting these scales at the subprovince level. Features were combined to form frameworks. With a large number of features to work with, the possible combinations were numerous. As the sub-groups worked through the development of the frameworks, it became apparent that for some subprovinces the available restoration features would not allow the achievement of all the prescribed scale levels.

Subprovince Frameworks

Subprovince 1 = 10 Alternatives
Subprovince 2 = 10 Alternatives
Subprovince 3 = 5 Alternatives
Subprovince 4 = 7 Alternatives

Nevertheless, the PDT's goal was to examine different approaches for meeting a specific scale. With that goal, the frameworks were intended to represent different hypotheses for ways to meet the various scales. Moreover, the alternatives needed to be distinct enough to provide for real choice among them. In planning terminology, the alternatives were developed to be "significantly different." So as not to make the analysis of alternative frameworks overly complex, the number developed for each subprovince to address a planning scale was limited to three, unless such a limit excluded a reasonable framework or restoration feature that would not otherwise be reviewed. These 32 alternatives were presented in four public meetings held in May and June 2003. Comments and recommendations received were considered to finalize the alternatives.

The Summary of Specific Alternative Frameworks (by Subprovince) section of the main report describes each of these frameworks. In addition, the specific frameworks provide detailed descriptions of each and its features.

5.1 Subprovinces 1 and 2

In the initial effort to develop alternatives for subprovinces 1 and 2, it became evident that there could be three different approaches (or frameworks) for meeting any given scale. Because the fundamental restoration approach for the Deltaic Plain is freshwater and sediment reintroduction, these three conceptual frameworks relate specifically to the design, operation, and ecosystem effects of reintroduction features. The following is a description of each conceptual framework, along with the rationale for its use:

Minimize Salinity Changes: Freshwater reintroductions affect salinity gradients and, therefore, can result in significant ecological changes. Many of the social and economic benefits currently provided by the ecosystem are based on the distribution of marsh types and salinity conditions that have prevailed for several decades. While the long-term goal of freshwater reintroductions is to ensure a healthy, productive, and sustainable coast, such features can change fisheries and wetland habitat types so that local harvesters and communities can no longer realize these benefits. The question then becomes whether it is possible to meet each planning scale in a way that minimizes such potential changes, while still providing for a sustainable coastal ecosystem. To answer this question, one alternative for each scale was developed in a way that seeks to minimize salinity changes. Alternatives consistent with this conceptual framework rely less on freshwater re-introduction and more on marsh creation using external sediment sources (including off-shore and riverine sources). Although the primary features for building marsh platforms are mechanical, limited freshwater reintroductions are included to help ensure the long-term sustainability of existing and restored wetlands. Additionally, the inclusion of freshwater reintroductions would provide an element of self-design, albeit to a relatively limited extent. This framework was applied throughout both subprovinces, in particular in the upper portion of Subprovince 1, where salinity increases are already recognized as a threat to the ecosystem and reducing salinity was a goal of any alternative.

Continuous Reintroduction (w/Stage Variation): In coastal Louisiana, the existing freshwater re-introduction projects (such as Davis Pond and Caernarvon) are for the most part operated with a continuous (i.e., year-round) flow, with discharge volume varying according to river stages and ceasing when river stages are too low. It is likely that the same approach to year-round reintroduction of water would provide effects at the larger scale that are not apparent with the existing diversions. Moreover, given that the natural deltaic process has been massively disrupted, the existing projects still fall far short of meeting the freshwater, nutrient, and sediment needs of subprovinces 1 and 2. By developing alternatives around a “continuous re-introduction” framework, the LCA process would be able to assess the potential benefits and costs of using more and larger reintroductions that operate year-round. This framework also allows for analysis of the water quality/hypoxia benefits that could be derived from maximum use of freshwater reintroduction.

Mimic Historic Hydrology: Alternatives under this conceptual framework are based on the assumption that historic hydrologic regimes (apart from river switching) in the Deltaic Plain Province were characterized by numerous, smaller seasonal freshwater inflows (from over-bank flow, small distributaries, and minor crevasses) combined with relatively short-term episodes of large freshwater inflows due to major flood-induced crevasses. Alternatives designed under this framework include numerous, smaller re-introductions combined with large reintroduction projects to be operated in periodic “pulsing” events. Consistent with this framework, the “increase” scale in Subprovince 2 includes the “Third Delta”, as well as relocation of navigation on the Mississippi River (to allow for more dynamic deltaic processes at the mouth of the river). Where appropriate, alternatives under this framework also include sediment enrichment of reintroduction waters to mimic the historically higher sediment loads in the Mississippi River. In addition to testing whether mimicking historic hydrology would meet the various scales, this conceptual framework may also provide a way to help restore deltaic processes, while minimizing any potential impacts associated with the year-round reintroduction features discussed above.

Using these three frameworks would not result in alternatives that are totally different from each other. Indeed, certain features may be included under all or many alternatives for a particular subprovince (e.g., barrier islands in Subprovince 2). Such common elements are often included because they either represent a structural component needed to make an alternative complete or are viewed as being valuable under a variety of scenarios. Moreover, where appropriate and consistent with the given conceptual framework, features were assembled in a way that sought to spread potential benefits throughout each subprovince. For example, though much of the "reduce" scale in Subprovince 1 could potentially be addressed by features taken in the upper portion of the subprovince, the use of such features was limited for the sake of developing alternatives with greater balance and geographic completeness. Finally, in using these frameworks to develop alternatives, care has been taken to ensure that reintroduction projects did not divert too much river flow, which could have consequences for navigation and possibly other existing uses of the river. The same consideration applies to some Subprovince 3 alternatives, as well to the combination of reintroduction alternatives from all three subprovinces.

5.2 Subprovince 3

Environmental and geologic conditions vary considerably across Subprovince 3. The western portion of the subprovince experiences lower subsidence rates and has the benefit of large volumes of freshwater, sediments, and nutrients flowing down the Atchafalaya River, resulting in ongoing deltaic growth. The eastern portion of the subprovince has a far higher land loss rate and has limited opportunities for freshwater reintroduction. The conceptual frameworks for Subprovince 3 reflect both the opportunities and the constraints facing wetland restoration in this area. Specifically, the frameworks represent different approaches to maximizing the use of potential and existing freshwater sources, while also restoring important geomorphic features.

<u>Maximum Atchafalaya Flow</u>: The ongoing deltaic land growth at the mouth of the Atchafalaya River and Wax Lake Outlet is both a rare source of new wetland acres in coastal Louisiana and a clear example of the benefits that can be derived from restoring deltaic processes. Alternatives developed under this framework seek to increase to the maximum extent possible the ongoing land growth, while also redirecting Atchafalaya River waters to help nourish wetlands in the Terrebonne Basin. In addition to improving natural deltaic processes, alternatives under this framework would involve mechanical features (i.e., sediment delivery) to further expedite and increase land growth. Increased flows down the existing Bayou Lafourche would also be assessed as a means for reducing loss rates in eastern Terrebonne Basin. Finally, as with the other conceptual frameworks for Subprovince 3, alternatives under this framework will include features designed to rehabilitate or maintain important geomorphic features, including barrier islands, land bridges, and gulf shorelines.

<u>Land Building by Delta Development</u>: Given the challenge of reintroducing significant amounts of freshwater, sediments, and nutrients to the eastern portion of Subprovince 3, it would take a massive effort to reestablish deltaic land growth in this area. The only feature potentially capable of doing so is the "Third Delta," an ambitious proposal to create a massive new distributary channel from the Mississippi River to both the Barataria and Terrebonne basins. To assess the effects of such a feature, alternatives developed under this conceptual framework

would center on implementation of the Third Delta. While relying primarily on this new distributary channel, these alternatives would also include moderate, complementary efforts to increase Atchafalaya Delta development, move Atchafalaya waters to the east, and restore critical geomorphic features.

Mississippi and Atchafalaya Flows: Alternatives developed under this conceptual framework represent a hybrid of the two former frameworks. Specifically, these alternatives would employ both the Third Delta, and more extensive efforts to increase Atchafalaya Delta development and move Atchafalaya River waters to the east, while also maximizing efforts to rehabilitate and maintain critical geomorphic features.

5.3 Subprovince 4

Salinity control has been identified as the "keystone strategy" for Subprovince 4. The increased water demands of Texas have also threatened the freshwater inflows that reduce salinity advancement up the Sabine River. With the proposed enlargement of the subprovince's navigation channels, the potential for increases in salinity and loss of vegetative marshes rises. Specifically, the deepening of Calcasieu and Sabine passes for navigation has been demonstrated to be the primary cause of increased salinity levels, which in turn have resulted in significant impacts to the area's wetland resources. Accordingly, the main conceptual frameworks for alternatives in Subprovince 4 represent different approaches to addressing the fundamental problem of increased salinities. The following is a description of the three conceptual frameworks:

Large-scale Salinity Control: The foundation of alternatives developed under this framework is large-scale salinity control structures (i.e., locks or gates) at Calcasieu Pass and Sabine Pass. Such structures would be designed and operated to ameliorate the salinity increases caused by the deepening of these passes for navigation purposes. While not exactly restoring the historic dimensions of the passes, these structures would have the effect of restricting saltwater inflows in the same general location that such restrictions existed in the past with minimum impacts to navigation. Theoretically, implementation of such an alternative could allow for modification or removal of existing upstream salinity control measures, thereby supporting the restoration of a more natural and less-managed hydrologic regime throughout the subprovince.

Perimeter Salinity Control: Alternatives developed under this conceptual framework are intended to reduce salinity impacts, while also avoiding any potential effects that locks or gates on the Calcasieu and Sabine passes may have on navigation. Specifically, this group of alternatives would include small-scale salinity control features around the perimeters of Calcasieu and Sabine lakes, thereby reducing saltwater intrusion to adjacent wetlands and waterways. Such structures would be state-of-the-art, designed to minimize disruption of organism and material linkages. However, unlike the large-scale salinity control alternatives, a perimeter approach would likely not limit any increased salinity of the current ecological character and social and economic uses of the Calcasieu and Sabine passes and lakes. This alternative would incorporate and build upon existing perimeter control structures.

Freshwater Introduction Salinity Control: Alternatives developed under this conceptual framework rely less on structural salinity-blocking features and more on hydrologic modifications to bring additional freshwater into the northern portion of the estuaries as the primary means for reducing salinities. Specifically, these alternatives would use culverts and other existing structures as conduits for increased flow of freshwater, which in turn would reduce salinity levels within the Calcasieu and Sabine estuaries. Freshwater introduction across Highway 82 in the Mermentau Basin would aide in reducing salinities in the Chenier Subbasin. Such alternatives would be intended to aid in the restoration of more natural hydrologic regimes, while having the added benefit of minimizing potential adverse socioeconomic impacts associated with the structural approaches considered in the first two frameworks--particularly with respect to the restriction of organism and material linkages and impacts to navigation.

As with the other LCA subprovinces, there are specific features that are common to many of the Subprovince 4 alternatives. For example, as recommended by some members of the National Technical Review Committee (NTRC), beneficial use of material dredged for navigation purposes is included in many alternatives. In addition, excessive impoundment of water has been identified as a major stressor of the wetlands. A number of alternatives do, therefore, include features to help reduce excessive water levels, in addition to allowing fresh water to flow southward to higher salinity areas, including the use of structures to improve freshwater flow across LA Highway 82. Finally, as with barrier islands to the east, gulf shoreline stabilization has been included throughout the alternatives in recognition of the critical function served by the Chenier Plain gulf barrier headland.

5.4 Summary of Specific Frameworks (By Subprovince)

A summary of the features included in each framework by subprovince is provided in this section (see **tables E-3** to **E-6**).

Subprovince 1--Mississippi East (Breton/Pontchartrain)

This section will address alternatives for Subprovince 1 with the following scales: (1) reduce, (2) maintain, and (3) increase the amount of wetlands in the subprovince area. There are a total of ten alternatives for this subprovince: three "reduce" (R); three "maintain" (M); three "increase" (E); and the supplemental framework (N) (**table E-3**).

Subprovince 2 -Mississippi West (Barataria)

This section will address alternatives for Subprovince 2 with the following scales: (1) reduce, (2) maintain and (3) increase the amount of wetlands in the Subprovince area. There are a total of ten alternatives for this subprovince: three "reduce" (R); three "maintain" (M); three "increase" (E); and the supplemental framework (N) (**table E-4**).

Subprovince 3 - Terrebonne, Atchafalaya and Teche / Vermilion

This section will address alternatives for Subprovince 3 with the following scales: (1) reduce and (2) maintain. There are a total of ten alternatives for this subprovince: three "reduce" (R); one "maintain" (M); and the supplemental framework (N) (**table E-5**).

Subprovince 4 - Chenier Plain

This section will address alternatives for Subprovince 4 with the following scales: (1) maintain and (2) increase. There are a total of ten alternatives for this subprovince: three "maintain" (M); three "increase" (E); and the supplemental framework (N) (**table E-6**).

Table E-3. Specific Alternatives, Subprovince 1.

Subprovince 1	R1	R2	R3	M1	M2	M3	E1	E2	E3	N1
15,000 cfs diversion at American / California Bay				x			x	x		
110,000 cfs diversion (div.) at American / California Bay with sediment enrichment			x		x					x
250,000 cfs div. at American / California Bay with sediment enrichment						x			x	
12,000 cfs div. at Bayou Lamoque		x	x		x	x		x	x	x
5,000 cfs div. at Bonnet Carre Spillway	x	x		x						
10,000 cfs div. at Bonnet Carre Spillway						x	x	x	x	
200,000 cfs div. at Caernarvon w/ sediment enrichment								x		
1,000 cfs div. at Convent / Blind River			x			x			x	
5,000 cfs div. at Convent / Blind River		x			x		x			x
10,000 cfs div. at Convent / Blind River								x		
15,000 cfs div. at Fort St. Philip			x	x			x			
26,000 cfs div. at Fort St. Philip w/ sediment enrichment						x				
52,000 cfs div. at Fort St. Philip w/ sediment enrichment									x	
1,000 cfs div. at Hope Canal	x	x	x	x	x	x			x	x
1,000 cfs div at Reserve Relief Canal									x	
6,000 cfs dive. at White's Ditch							x			
10,000 cfs div. at White's Ditch		x	x		x	x			x	x
Sediment delivery by pipeline at American/ California Bay				x			x		x	
Sediment delivery via pipeline at Central Wetlands	x			x			x			
Sediment delivery via pipeline at Fort St. Philip				x			x			
Sediment delivery via pipeline at Golden Triangle							x			
Sediment delivery via pipeline at La Branche	x			x			x			x
Sediment delivery via pipeline at Quarantine Bay	x						x			
Authorized opportunistic use of the Bonnet Carre Spillway.										x
Increase Amite River influence by gapping dredged material banks on diversion canals.										x
Marsh nourishment on the New Orleans East land bridge.										x
Mississippi River Delta Management Study.										x
Mississippi River Gulf Outlet Environmental Features and Salinity Control Study.					x		x			x
Reauthorization of the Caernarvon freshwater diversion. (optimize for marsh creation).										x
Rehabilitate Violet Siphon and post authorization for the diversion. of water through Inner Harbor Navigation Canal for enhanced influence into Central Wetlands.										x

Note: Gross rates of restored/ protected wetlands: R = Reduce, 406 ac/yr; M = Maintain, 806 ac/yr ; E = Increase, -1,209 ac/yr; Scales: 1 = Minimize salinity change; 2 = Continuous reintroduction; 3 = Mimic historic hydrology. Description of the features can be found in Section 2.6 of the main report.

Table E-4. Specific Alternatives, Subprovince 2.

Subprovince 2	R1	R2	R3	M1	M2	M3	E1	E2	E3	N1
5,000 cfs diversion (div.) at Bastion Bay/Buras			x							
130,000 cfs div. at Bastion Bay/Buras		x								
120,000 cfs div. near Bayou Lafourche									x	
60,000 cfs div. at Boothville w/ sediment enrichment.										x
1,000 cfs div. at Donaldsonville		x	x		x	X				x
5,000 cfs div. at Donaldsonville w/ sediment enrichment								x		
1,000 cfs div. at Edgard		x	x		x	X				x
5,000 cfs div. at Edgard w/ sediment enrichment	x							x		
5,000 cfs div. at Empire			x							
90,000 cfs div. at Empire								x		
5,000 cfs div. at Fort Jackson			x							
60,000 cfs div. at Fort Jackson	x			x						
60,000 cfs div. at Fort Jackson w/ sediment enrichment						X	x	x		
90,000 cfs div. at Fort Jackson w/ sediment enrichment									x	
150,000 cfs div. at Fort Jackson w/ sediment enrichment					x					
1,000 cfs div. at Lac des Allemands		x			x	X				x
5,000 cfs div. at Lac des Allemands w/ sediment enrichment				x			x	x	x	
5,000 cfs div. at Myrtle Grove	x		x	x			x			x
15,000 cfs div. at Myrtle Grove		x								
38,000 cfs div. at Myrtle Grove w/ sediment enrichment					x					
75,000 cfs div. at Myrtle Grove w/ sediment enrichment						X				
150,000 cfs div. at Myrtle Grove w/ sediment enrichment								x		
5,000 cfs div at Oakville			x							
1,000 cfs div. at Pikes Peak		x	x		x	X				x
5,000 cfs div. at Pikes Peak w/ sediment enrichment								x		
5,000 cfs div. at Port Sulphur			x							
Barrier Island restoration at Barataria Shoreline	x	x	x	x	x	X	x	x	x	x
Marsh creation at Wetland Creation and Restoration feasibility study sites	x			x			x		x	x
Mississippi River Delta Management Study.										x
Reauthorization of Davis Pond.										x
Relocation of Deep Draft Navigation Channel							x		x	
Sediment delivery via pipeline at Bastion Bay				x			x			
Sediment delivery via pipeline at Empire			x	x			x			
Sediment delivery via pipeline at Head of Passes				x			x			
Sediment delivery via pipeline at Myrtle Grove	x			x			x			x
Third Delta Re-evaluation										x

Note: Gross rates of restored/ protected wetlands: R = Reduce, 406 ac/yr; M = Maintain, 806 ac/yr ; E = Increase, -1,209 ac/yr; Scales: 1 = Minimize salinity change; 2 = Continuous reintroduction; 3 = Mimic historic hydrology. Description of the features can be found in Section 2.6 of the main report.

Table E-5. Specific Alternatives, Subprovince 3.

Subprovince 3	R1	R2	R3	M1						N1
Backfill pipeline canals			x	x						
Bayou Lafourche 1,000 cfs pump	x	x		x						x
Convey Atchafalaya River water to Terrebonne marshes	x		x	x						x
Freshwater introduction south of Lake De Cade	x	x		x						
Freshwater introduction via Blue Hammock Bayou	x	x		x						x
Increase sediment transport down Wax Lake Outlet	x	x		x						x
Maintain land bridge between Bayous Dularge and Grand Caillou	x		x	x						x
Maintain land bridge between Caillou Lake and Gulf of Mexico.			x	x						x
Maintain northern shore of East Cote Blanche Bay at Pt. Marone			x	x						x
Maintain Timbalier land bridge			x	x						
Multipurpose operation of the Houma Navigation Canal (HNC) Lock.	x	x	x	x						x
Penchant Basin Plan	x	x	x	x						x
Rebuild historic reefs – Rebuild historic barrier between Point Au Fer and Eugene Island	x	x	x	x						
Rebuild historic reefs – Construct segmented reef/breakwater/jetty along the historic Point Au Fer barrier reef from Eugene Island extending towards Marsh Island to the west	x	x	x	x						
Rebuild Point Chevreuil Reef			x	x						x
Rehabilitate northern shorelines of Terrebonne/Timbalier Bays			x	x						
Relocate the Atchafalaya navigation channel	x	x		x						x
Restore Terrebonne barrier islands.			x	x						x
Stabilize banks of Southwest Pass			x	x						
Stabilize gulf shoreline of Point Au Fer Island			x	x						x
Study the modification of the Old River Control Structure (ORCS) Operational Scheme to Benefit Coastal Wetlands	x	x		x						x
Third Delta (120,000 cfs diversion)		x		x						

Note: Gross rates of restored/ protected wetlands: R = Reduce, 406 ac/yr; M = Maintain, 806 ac/yr ; E = Increase, -1,209 ac/yr; Scales: 1 = Minimize salinity change; 2 = Continuous reintroduction; 3 = Mimic historic hydrology. Description of the features can be found in Section 2.6 of the main report.

Table E-6. Specific Alternatives, Subprovince 4.

Subprovince 4				M1	M2	M3	E1	E2	E3	N1
Black Bayou Bypass culverts.										x
Calcasieu Pass Lock				x			x			
Calcasieu Ship Channel Beneficial Use				x	x	x	x	x	x	x
Chenier Plain Freshwater Management and Allocation Reassessment.										x
Dedicated Dredging for Marsh Restoration					x	x		x	x	
East Sabine Lake Hydrologic Restoration					x			x		x
Freshwater introduction at Highway 82				x	x	x	x	x	x	x
Freshwater introduction at Little Pecan Bayou				x	x	x	x	x	x	x
Freshwater introduction at Pecan Island				x	x	x	x	x	x	x
Freshwater introduction at Rollover Bayou				x	x	x	x	x	x	x
Freshwater introduction at South Grand Chenier				x	x	x	x	x	x	x
Freshwater introduction via Calcasieu Lock and Black Bayou culverts						x			x	
Gulf Shoreline Stabilization					x		x	x	x	x
Modify existing Cameron-Creole Watershed Control Structures					x			x		x
New Lock at the GIWW					x			x		
Sabine Pass Lock				x			x			
Salinity control at Alkali Ditch					x			x		x
Salinity control at Black Bayou					x			x		x
Salinity control at Black Lake Bayou					x			x		x
Salinity control at Highway 82 Causeway					x	x		x	x	x
Salinity control at Long Point Bayou.					x			x		x
Salinity control at Oyster Bayou					x			x		x

Note: Gross rates of restored/ protected wetlands: R = Reduce, 406 ac/yr; M = Maintain, 806 ac/yr ; E = Increase, -1,209 ac/yr; Scales: 1 = Minimize salinity change; 2 = Continuous reintroduction; 3 = Mimic historic hydrology. Description of the features can be found in Section 2.6 of the main report.

5.5 Evaluation of Subprovince Frameworks

The evaluation methodology for the frameworks was developed to capture their systemic relationships and outputs/benefits on a subprovince-wide scale. The evaluation involved a multi-tiered modeling and data processing structure combining hydrodynamic simulation through numerical modeling, ecological change projection through linked database computation, and database processing of modeling and change projections to produce a final estimate of framework outputs.

Alternatives within the subprovinces were evaluated using three consecutive analytic processes: simulation models, desktop models, and restoration benefit calculation (**figure E-2**). Simulation models are used to determine hydrodynamic endpoints. The next step, desktop modeling, is used to determine attributes associated with alternatives such as habitat use, water quality, land building, and habitat switching. Finally, restoration benefits are evaluated for each alternative or combination of alternatives.

5.5.1 Model Analyses

The relationship between the simulation and desktop modeling is developed through the output from the hydrodynamics model (**figure E-3**). This output is delivered to the land building, habitat switching, and water quality modules. The hydrodynamic output quantities include sediment, water level, salinity, and rate of flow. The next relationship is between land building and habitat switching modules and habitat use module. Land/water ratios output from the land building modules are used in the habitat use module. Also, from the habitat switching module, habitat types are used in the habitat use module.

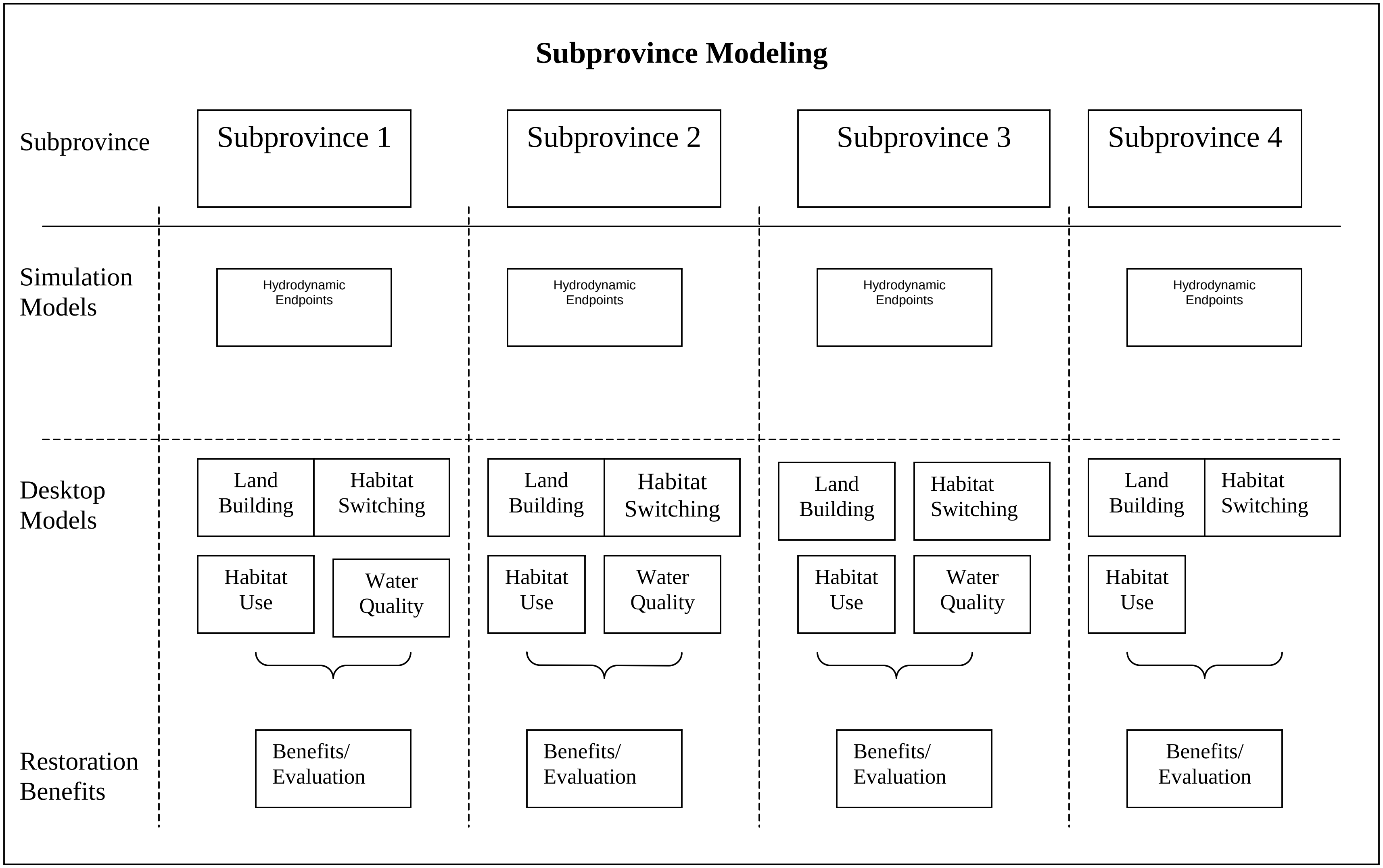

Figure E-2. Modeling Processes Used in the Various Subprovinces.

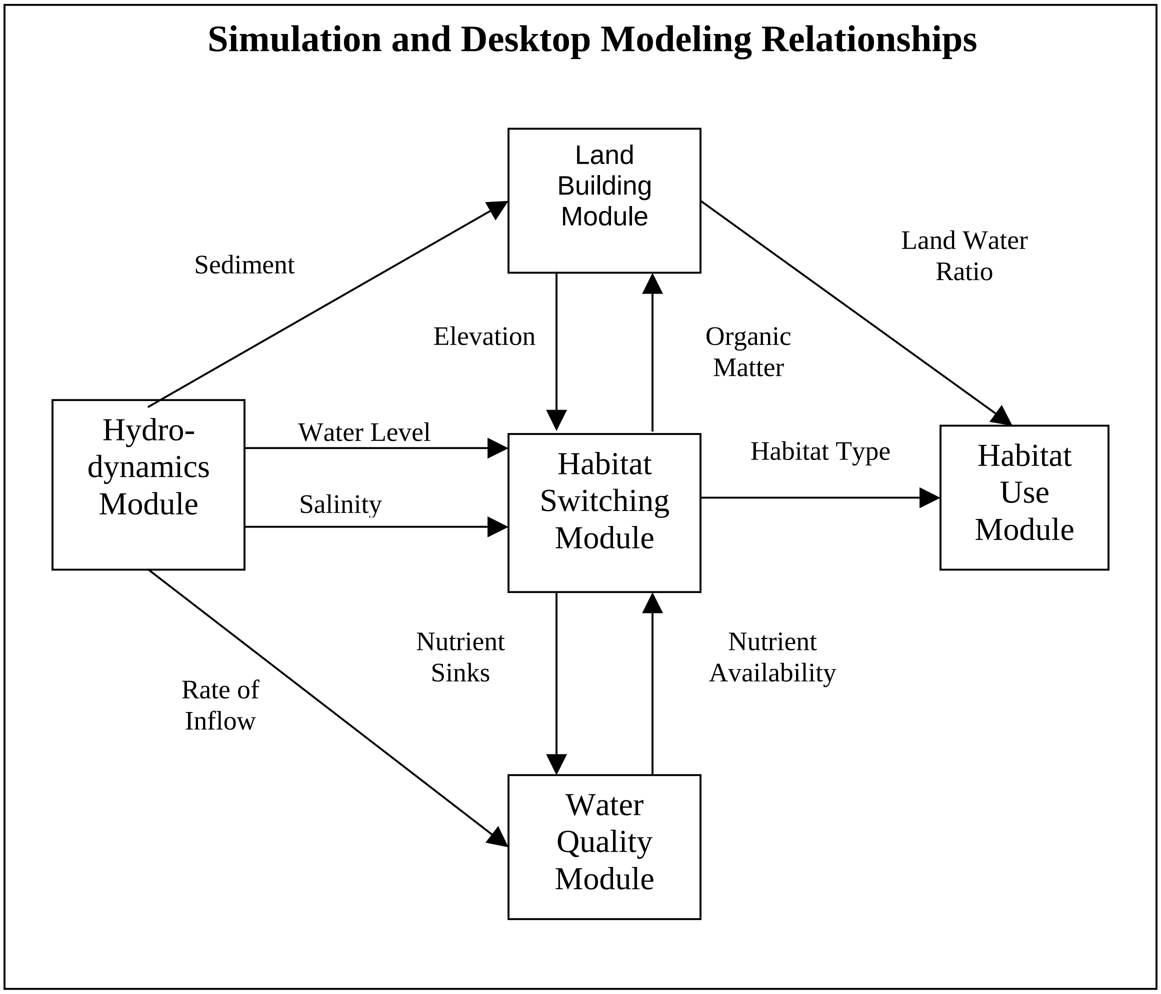

Figure E-3. The Relationship Among the Various Modules of the Desktop Model.

The PDT relied on existing and previously tested hydraulic models within the study area to address hydrology and salinity distribution. Hydrodynamic models existed within all the study subprovinces. The desktop models were based on linked spreadsheets and were developed for all the subprovinces to project land building, habitat switching, habitat use, and water quality. The benefit computation methodology was developed to utilize the output provided by the desktop models to estimate the ecological output of each framework. The PDT also called upon a combination of academic and interagency support for the modeling effort. As the developers of the existing models, they were best able to execute the required simulations.

To establish inputs for the hydraulic models, discharge rating curves for each proposed diversion feature were developed. The criteria for these designs were a stated nominal discharge (at the 50 percent exceedence stage) of the Mississippi River at that location. A digital record of daily stages for each Mississippi River gage for the period of analysis (1977-2002) was used to determine the 50 percent exceedence stages along the river throughout the study area. The number of daily values for the period of record was totaled and the minimum and maximum stage values identified. The total range of the record for each gage was divided into equal stage increments, and the total number of values equal to or greater than each increment was determined. The percentage of the values that is equal to or greater than a particular increment value can then be computed. Therefore, 100 percent of the values in the record will equal or exceed the minimum stage value at a given gage. The maximum stage value for a given gage would be exceeded zero percent of the time. The term 50 percent “duration” stage was used to signify the stage value that is exceeded 50 percent of the time.

The stages that were equaled or exceeded 50 percent of the time on a yearly basis were used in sizing the diversion structures and developing discharge curves at various locations along the river. Therefore, the description for a 5,000-cubic foot per second (cfs) diversion refers to the “nominal” capacity of the diversion. The diversions are capable of delivering substantially more flow than the nominal capacity since the river stages at a particular location will be greater than the yearly 50 percent duration stage at least one-half of the time. Conversely, half of the time the diversion will pass less than 5,000 cfs, and for some locations, when river stages are very low, the diversion will not pass any flow from the river into the receiving area.

While at any given river location the correlation between the 50 percent duration stage and the average discharge of the Mississippi River is not exact for the purposes of diversion sizing and determining flow budget, these two values are assumed to be equivalent. Therefore, the sum of the design flows for the diversions in any alternative framework reflects the total volume of flow that would be diverted from the river at its annual average discharge.

The basic protocol for the evaluation effort was for the use of the existing hydrodynamic models to simulate base conditions and up to three framework configurations for one year. The model simulations focused primarily on the effects of changing freshwater input to a system where appropriate. In Subprovince 4 (Chenier Plain), the frameworks focused heavily on management of tidal exchange and therefore the model simulations did as well. The model simulations provided a range of effects for a representative number of frameworks in each subprovince. Members of the PDT were then able to extrapolate the salinity effects for the remaining frameworks in each subprovince as necessary. In a similar manner, where other numeric models were able to simulate specific effects, output for simulated frameworks was used to verify the desktop projections for additional frameworks.

The basis for the desktop models was a series of linked spreadsheets containing algorithms or equations for various components of ecological change and quality. The cells of the spreadsheets were correlated to 1-km-square grid cells laid across the coastal landscape, thus simulating spatial expression. For each ecological component the database contains a series of cells representing months of the year and therefore producing a 1-year simulation. Successive linked spreadsheets produce the effect of projecting the ecological components over a corresponding number of years, or time steps of multiple years, if desired.

The salinity output, either from the numeric simulations or through extrapolation, provided the basic input for the desktop models. This information was combined with basic volumetric data regarding river sediment load, mechanically introduced sediment load, and flow rates for individual framework features. Parameters of location and time for the mechanical placement of dredged sediment to create land were also provided as input to the desktop models.

Desktop model outputs consisted of 15 output categories that include: habitat suitability of 12 fauna, nitrogen removal, primary productivity, and wetlands acreage. The 12 fauna (Habitat Suitability Index (HSI)) outputs are valued between 0 and 1. These fauna are categorized by salinity preference as follows: high salinity (juvenile brown shrimp, juvenile white shrimp, juvenile spotted seatrout), medium salinity (oysters, juvenile Atlantic croaker, juvenile gulf menhaden, muskrat), and low salinity (largemouth bass, mink, otter, dabbling duck, alligator).

5.5.2 Benefit Assessment Protocols

Benefit protocols were developed to synthesize the ecosystem dynamics information being generated by the desktop models in the assessment of LCA alternatives (**table E-7**). The information covers an array of ecosystem attributes and functions, and the benefits protocols provide a means of comparing complex patterns, both in space and time, of ecosystem change. The protocols were formulated and developed by a multi-disciplinary team of agency experts and university scientists with extensive experience of both the Louisiana coastal ecosystem and of the use of ecosystem benefits features in restoration planning and assessment.

The benefit protocols each contribute to the decision making process in different ways. Benefit protocol #2 was used as input to IWR-Plan as part of the incremental cost-effectiveness analysis. The other benefits protocols provide additional information on specific aspects of an ecosystem as well as measure the effectiveness of alternative frameworks relative to the two ecosystem objectives identified for the LCA Plan. Those objectives are: increase land-water ratios, increase connectivity and material exchanges to improve *productivity* and sustain diverse *fish and wildlife habitats*, and reduce nutrient delivery to the shelf by routing Mississippi River waters through estuarine basins. These data were used to inform the decision makers as they developed an implementation strategy using the IWR-Plan results.

Table E-7 summarizes the role of each of the six benefit protocols developed to support LCA decision-making. A detailed description of the rationale for each protocol and the specifics of the algorithms to be used are provided in a separate document.

Table E-7.
Summary Description of LCA Benefit Protocols

Protocol #	**Aspect of Ecosystem Change**	**Essential inputs**
B1	Productivity and Habitat use – Habitat Quality	Primary productivity of land and water Use of habitat by 12 coastal species
B2	Quantity of land, Quality of habitat and Nitrogen removal	Acres of land Primary productivity of land and water Use of habitat by 12 coastal species Removal of N from Mississippi River water.
B3	Quantity of land	Acres of land
B4	Nitrogen removal	Removal of N from Mississippi River water
B5	Value of fish and wildlife habitat	Use of habitat by 12 coastal species
B6	Selected stakeholder interest issues	Various combinations of the assessment output (see detailed description below)

All benefit values represent the net difference between the future with the alternative (FWA) and No Action alternative, or the future without the alternative (FWO). This calculation is made for each protocol with benefit values for all alternatives, including No Action. The ordering of the protocols reflects the team development process and does not imply an order in which they will be applied or any priority ranking.

Some of the inputs in **table E-7** were available from the desktop models at a resolution of $1km^2$ across the coast. Thus 1 km^2 is the smallest scale at which any of the protocols can be applied. Others are, by definition, values that describe the effect of an alternative at the subprovince scale (e.g., acres of land). The vast array of information provided by the alternatives assessment process allows the individual benefits protocols to use input at many spatial scales across the coast. In all cases the protocols seek to reflect the effect of the alternative on the entire subprovince.

While the models used to generate the output were applied at various time steps, the desktop approach allows benefits to be calculated in annual increments. The protocols that produce information in “unit” form (e.g., habitat units) could be accumulated at ten-year intervals to provide information on benefits over 50 years, or benefits over shorter intervals both as a net value and as average annual benefits.

Benefit Protocol B1--Quality of Habitat--was developed to reflect the relative progress made by alternatives in reaching Ecosystem Objective #1. It combines two components:

- Primary Productivity
- Habitat Use

Values for each component are derived, as described below, for each 1 km^2 cell and combined to produce a HSI that reflects quality of habitat (HSIQL). The HSIQLs of all cells within a subprovince are totaled to account for the area of the subprovince and produce habitat quality units (HQUs).

Benefits Protocol B2—Composite Benefits--is the protocol used to generate values for input into the IWR-Plan. It is one number generated from three individual benefit protocols, which indicates the achievements of the alternative in meeting ecosystem objectives 1 and 2 and also indicates the success in creating or preserving land. The three components combined to produce this value were:

- Quality of Habitat
- Quantity of Land
- Nitrogen removal

Values for each component are derived for each 1 km^2 cell and combined to produce an overall suitability index (OSI). The OSIs of all cells within a subprovince are totaled to account for the area of the subprovince and produce benefits units (BUs).

Benefits Protocol B3--Quantity of Land--measures the achievement of the alternative in creating and preserving land within the subprovince. As all benefits are expressed relative to No Action, B3 consists of the amount of land (including wetlands, barrier islands, ridges, etc., but not fastlands, which are excluded by the subprovince boundary) produced by the alternative after 50 years. The units are in acres.

Benefits Protocol B4--Nitrogen Removal--gauged the alternatives in meeting ecosystem objective #2 by assessing the amount of nitrogen removed by the alternative in tons per year, as provided by the water quality desktop module. To put this in the context of overall frameworks for nutrient reduction in the Mississippi River, this value is presented relative to the Action Plan goal developed by the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force that was presented to the U.S. Congress in January 2001. The action plan calls for a 30 percent reduction in nitrogen loading. The mean annual load of total nitrogen delivered to the Gulf of Mexico is 1,763,698 tons [1.6 million metric tons] (CENR 2000). A 30 percent reduction of this would be 529,109 tons [480,000 metric tons] annually.

Benefits Protocol B5--Value of Fish and Wildlife--reflects the fish and wildlife habitat value for each marsh habitat type (i.e., fresh/intermediate, brackish, and saline) within a subprovince. The habitat use desktop models will provide an HSI for each species (listed in **table E-8**) for each 1 km^2 cell.

Table E-8.
Species Included in Benefit and Variable Designations

V1 White shrimp	V7 Largemouth bass
V2 Brown shrimp	V8 American alligator
V3 Oyster	V9 Muskrat
V4 Gulf menhaden	V10 Mink
V5 Spotted seatrout	V11 Otter
V6 Atlantic croaker	V12 Dabbling ducks

The HSI values were averaged across all cells, for each habitat type, for each species, being used to determine habitat quality for that zone. Each species was weighted based on its relative importance in determining habitat quality for a specific habitat type. For instance, in the fresh/intermediate model, brown shrimp, oyster, and spotted seatrout are not used (or weighed with a zero) because they are not important in determining habitat quality in that zone.

Benefits Protocol B6--Selected Stakeholder Interests--includes features that reflect aspects of ecosystem change which are of specific interest to stakeholders or resource agencies. The features included here will likely change as the decision-making process proceeds and issues arise for which information regarding alternative performance is required.

6.0 SELECT A FINAL ARRAY OF COASTWIDE FRAMEWORKS THAT BEST MEETS PLANNING OBJECTIVES (TO BE ACCOMPLISHED AFTER PUBLIC COORDINATION) (PHASE V)

The PDT created the coastwide frameworks that were composed from each province and evaluated them using the Institute for Water Resources (IWR)-Plan computer program (Version 3.3, USACE). The automated program grouped the 32 subprovince frameworks into thousands of different combinations. The program then performed a cost effectiveness and incremental cost analysis (CE/ICA) using outputs/benefits and the estimated costs, that had been previously developed in the initial plan formulation phases, summed for the combined groups restoration features.

The benefits of the project alternatives are defined in ecological habitat units. Consequently, the analytical approach selected produced a comparison of costs expressed in dollars to benefits stated in habitat units. A CE/ICA was performed using this data.

In the cost-effectiveness analysis, the frameworks were assessed according to their ability to produce total ecological outputs for a given cost level. Frameworks that maximize output per dollar spent were retained, while all other frameworks were eliminated. The result is a listing of frameworks that achieve each output level at the lowest cost, or an efficient frontier. The cost-